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FIRST DETERMINATIONS OF PHOTOELECTRIC MINIMA, REAL PERIOD AND STUDY OF THE PERIOD OF NP Pav

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NP Pav was discovered by Hoffmeister (1949) who published a finder chart (1957). Shaw and Sievers (1970) found that it is an EA object, with a period of $1^{\rm d}.266821$ and a deep secondary minimum. They also published a list of minima and a finder chart.

We present here the first photoelectric determinations of minima of the eclipsing binary NP Pav = S 5117 = KSP 5263 = BV 1305 = GSC 9321:1055. The observations were made during three runs, all from Cerro Tololo Inter-American Observatory[1] in Chile with the Lowell telescope and single-channel photon counting techniques and standard UBV filters. In 1982 and 1984 a refrigerated phototube EMI 2070 was used while in 1995 a refrigerated phototube RCA 31034A was utilized. GSC 9308:1513 = CPD $-69°3134$ ($9^{\rm m}.6$) served as the comparison and GSC 9321:1105 = CPD $-69°3146$ ($6^{\rm m}.7$) = CoD $-69°1958$ ($7^{\rm m}.1$) = SAO 254907 = HD 198971 (B9/9.5V $6^{\rm m}.9$) as the check.

The photoelectric light curve is completed in the three filters U, B and V. It is presented in Figure 1 together with their color index curves $u - b$ and $b - v$. The light curve shows a shallow secondary minimum of $0^{\rm m}.225$ depth in V, therefore the period must be reduced to half of the value. The depth of the primary minimum is $1^{\rm m}.075$ in V. The eclipse is almost complete and the portion of the light curve that is included into the eclipse is measured by the external tangent angle that is 0.12 in phase units. The $b - v$ color is somewhat redder by about $0^{\rm m}.025$ in V around the primary minimum and bluer for the same amount around the secondary minimum. Outside the minima the light curve is not constant showing the proximity effects.

The photographic minima were scaled to the new period and a dispersion of 0.02 incorporated to all of these minima. The linear solution is Min I = HJD 2438234.4014 + $0^{\rm d}.6334113 \times E$ with an error of $0^{\rm d}.0042$ for the day and $0^{\rm d}.0000027$ for the period. Two sets of photoelectric minima, one of only one minimum in 1984 and the other with six minima in 1995, were derived by the polynomial line method (Guarnieri et al. 1975, Ghedini 1982). A least square solution for the photoelectric times of minima gives:

$$\begin{aligned} \text{Min I} = \text{HJD } 2445984.7095 &+ 0^{\rm d}.63353658 \times E \\ \pm 0.0011 &\pm 0.00000020 \text{ m.e.,} \end{aligned} \tag{1}$$

without a term of the second order, in other words, the period in the photoelectric part has remained in first approximation constant. In Table 1 are shown the photoelectric minima,

[1] NOAO with is operated by AURA Inc. under cooperative agreement with the NSF

Table 1: Times of photoelectric minima and residuals for linear ephemeris of NP Pav

Min.	Band	HJD(sigma) 2400000 +	E	$O-C$
I	U	45984.7094(0.0010)	0.0	−0.0001
I	B	45984.7093(0.0012)	0.0	−0.0002
I	V	45984.7098(0.0014)	0.0	0.0003
II	U	49945.9004(0.0037)	6252.5	0.0035
II	B	49945.8995(0.0028)	6252.5	0.0026
II	V	49945.8995(0.0026)	6252.5	0.0026
I	U	49946.8478(0.0010)	6254.0	0.0006
I	B	49946.8476(0.0012)	6254.0	0.0004
I	V	49946.8478(0.0011)	6254.0	0.0006
II	U	49947.7943(0.0027)	6255.5	−0.0032
II	B	49947.7974(0.0011)	6255.5	−0.0001
II	V	49947.7963(0.0017)	6255.5	−0.0012
I	U	49948.7495(0.0011)	6257.0	0.0016
I	B	49948.7491(0.0014)	6257.0	0.0012
I	V	49948.7487(0.0021)	6257.0	0.0008
I	U	49951.9113(0.0038)	6262.0	−0.0042
I	B	49951.9108(0.0018)	6262.0	−0.0047
I	V	49951.9108(0.0012)	6262.0	−0.0047
II	U	49959.8388(0.0026)	6274.5	0.0041
II	B	49959.8357(0.0016)	6274.5	0.0010
II	V	49959.8354(0.0011)	6274.5	0.0007

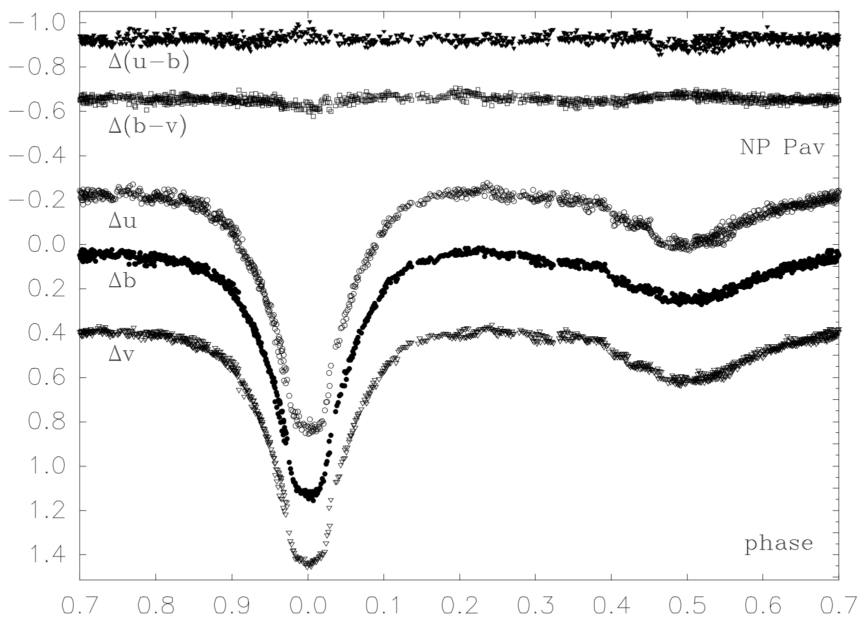

Figure 1. Complete light and color curve of NP Pav. The vertical scale corresponds to δv, the shifts are: $\delta b = -0.402$, $\delta u = -0.651$, $\delta(b-v) = -0.711$, $\delta(u-b) = -0.898$

Table 2: Times of minima and residuals for parabolic and linear ephemeris of NP Pav

Ref.	Min.	Band	HJD(sigma) 2400000 +	E	$O-C$	$(O-C)'$
1	I	pg.	38234.4080(0.0200)	−12236.0	−0.0037	0.0082
1	I	pg.	38258.4520(0.0200)	−12198.0	−0.0289	−0.0176
1	I	pg.	38260.3610(0.0200)	−12195.0	−0.0201	−0.0088
1	I	pg.	38307.2330(0.0200)	−12121.0	−0.0198	−0.0095
1	I	pg.	38314.2310(0.0200)	−12110.0	0.0108	0.0209
1	I	pg.	38555.5490(0.0200)	−11729.0	0.0029	0.0080
1	I	pg.	38562.5120(0.0200)	−11718.0	−0.0015	0.0035
1	I	pg.	38614.4370(0.0200)	−11636.0	−0.0155	−0.0115
1	I	pg.	38614.4650(0.0200)	−11636.0	0.0125	0.0165
1	I	pg.	38621.4280(0.0200)	−11625.0	0.0081	0.0120
1	I	pg.	38640.3980(0.0200)	−11595.0	−0.0239	−0.0204
1	I	pg.	38642.3110(0.0200)	−11592.0	−0.0111	−0.0077
1	I	pg.	38649.3110(0.0200)	−11581.0	0.0215	0.0248
1	I	pg.	38675.2400(0.0200)	−11540.0	−0.0190	−0.0162
1	I	pg.	38694.2500(0.0200)	−11510.0	−0.0110	−0.0086
1	I	pg.	39029.3330(0.0200)	−10981.0	0.0027	−0.0010
1	I	pg.	39373.2820(0.0200)	−10438.0	0.0148	0.0054
1	I	pg.	39378.3280(0.0200)	−10430.0	−0.0064	−0.0159
1	I	pg.	39385.3340(0.0200)	−10419.0	0.0322	0.0226
1	I	pg.	40089.0310(0.0200)	−9308.0	0.0203	0.0010
1	I	pg.	40096.0070(0.0200)	−9297.0	0.0289	0.0095
1	I	pg.	40419.0310(0.0200)	−8787.0	0.0182	−0.0048
1	I	pg.	40450.0620(0.0200)	−8738.0	0.0126	−0.0107
2	I	U	45984.7094(0.0010)	0.0	−0.0006	−0.0001
2	I	B	45984.7093(0.0012)	0.0	−0.0007	−0.0002
2	I	V	45984.7098(0.0014)	0.0	−0.0002	0.0003

References: 1 photographic minima; 2 photoelectric minimum of 1984.

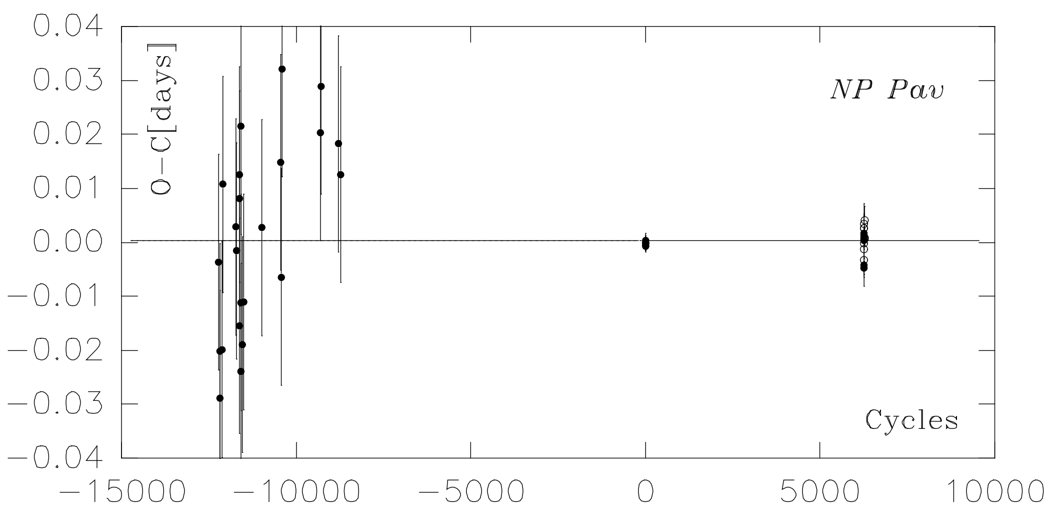

Figure 2. Behavior of the $O-C$ residuals for NP Pav from formulae (1) and (2). Hollow circles stand for primary minima, vertical bars are for errors

the dispersion associated with each minimum, the epoch numbers and the $O-C$ residuals respect to (1). It was not possible to find a common solution for both the photographic and the photoelectric minima. The photographic and the 1984 photoelectric minima gives the following formula:

$$\begin{array}{l} \text{Min I} = \text{HJD } 2445984.7095 + 0\overset{\text{d}}{.}6333894 \times E - 1\overset{\text{d}}{.}04 \times 10^{-9} \times E^2 \\ \qquad\qquad\qquad\qquad \pm 0.0019 \pm 0.0000030 \qquad \pm 0.26 \times 10^{-9} \end{array} \quad (2)$$

which is quadratic. This is shown in Table 2 that is similar to Table 1, where the $O-C$ and $(O-C)'$ are the residuals respect to the linear and parabolic solution.

Although comparing the periods of the photographic solution ($0\overset{\text{d}}{.}6334113[27]$) with that corresponding to the photoelectric solution ($0\overset{\text{d}}{.}63353658[20]$) the period varies and the second order term in (2) is not negligible, the large errors of the $(O-C)'$ values implies, that the quadratic fit seems to be not reliable (suggested by a referee). We consider that in a first approximation the period has remained constant during all the 'history' of this system. The formula (1) that is all photoelectric is to be used for derive new times of minima. The $O-C$ diagram is displayed in Figure 2.

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